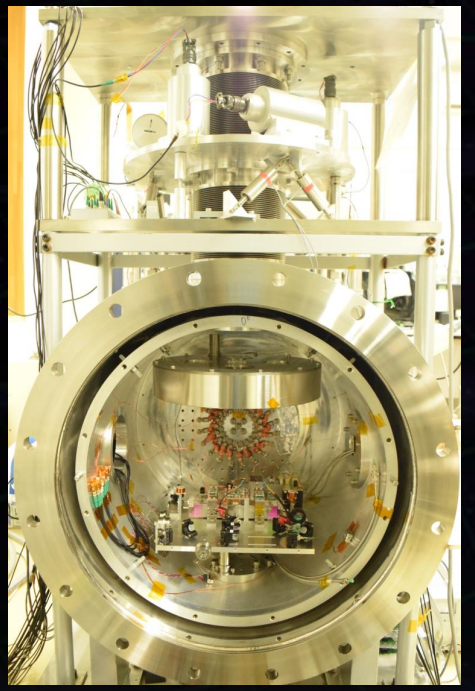
Status of TOBA

Masaki Ando (Univ. of Tokyo),
N. Aritomi, T. Shimoda, D. Fiorucci,
C. P. Ooi, A. Shoda, Y. Kuwahara,
Y. Michimura



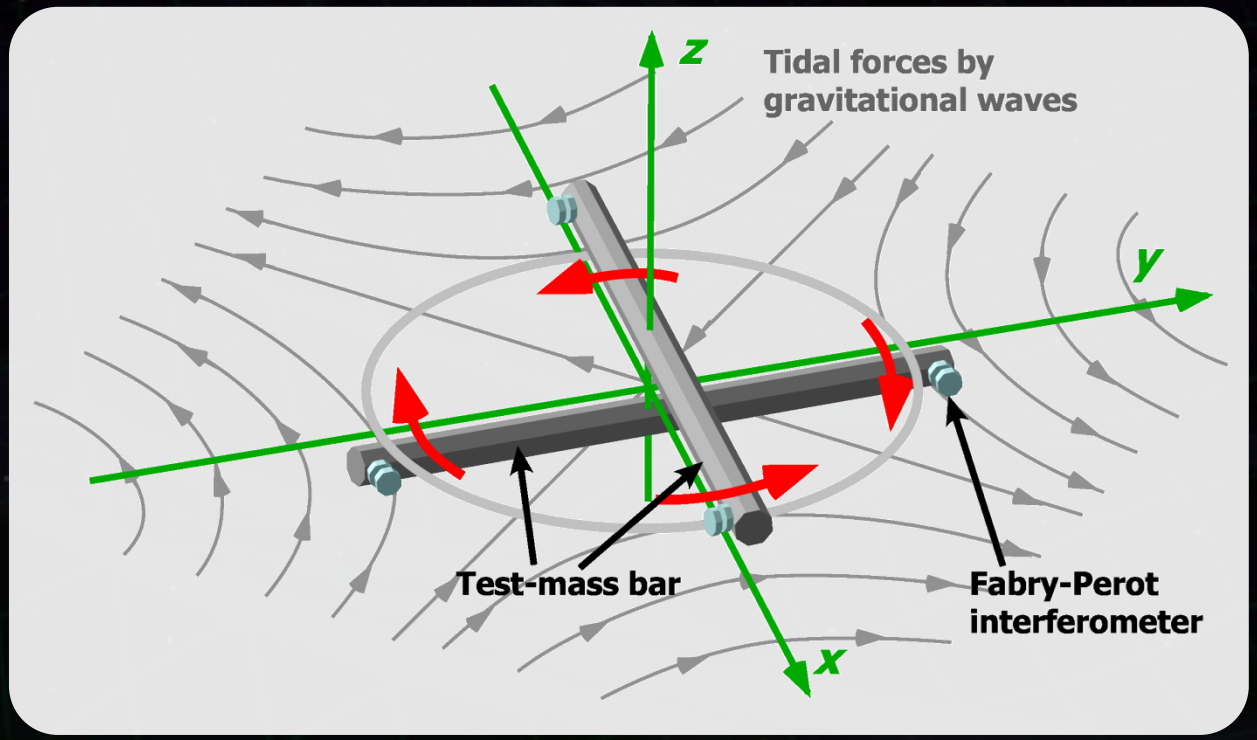
Phase-II.5 TOBA at Tokyo

Torsion-Bar Antenna

TOBA: Torsion-Bar Antenna

Two bars suspended as torsion pendulums

⇨ Detect differential rotation by GW



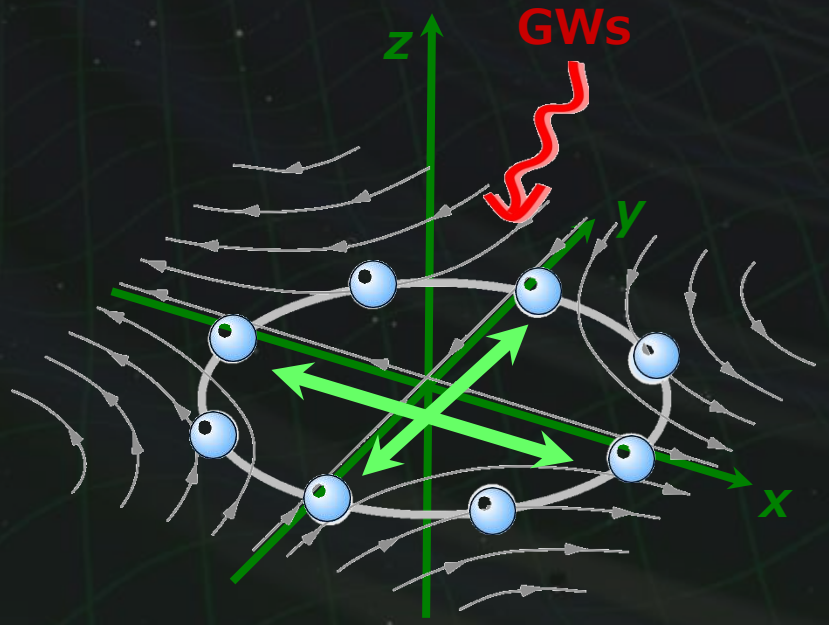
M. Ando+, Phys. Rev. Lett. (2010)

Strain and Rotation

Low resonant freq. in a torsion pendulum

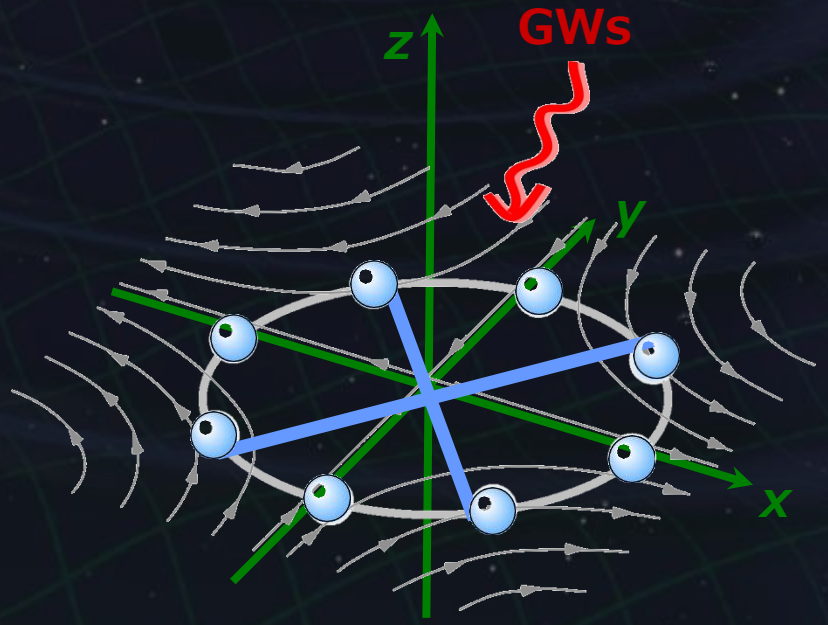
→ Fundamental sensitivity to low-freq. GW.

Traditional IFO detector



Differential Strain $h \sim \frac{\delta L}{L}$

Torsion Bar Detector



Differential Rotation $h \sim \delta\theta \sim \frac{\delta L}{L}$

Additional Motivations

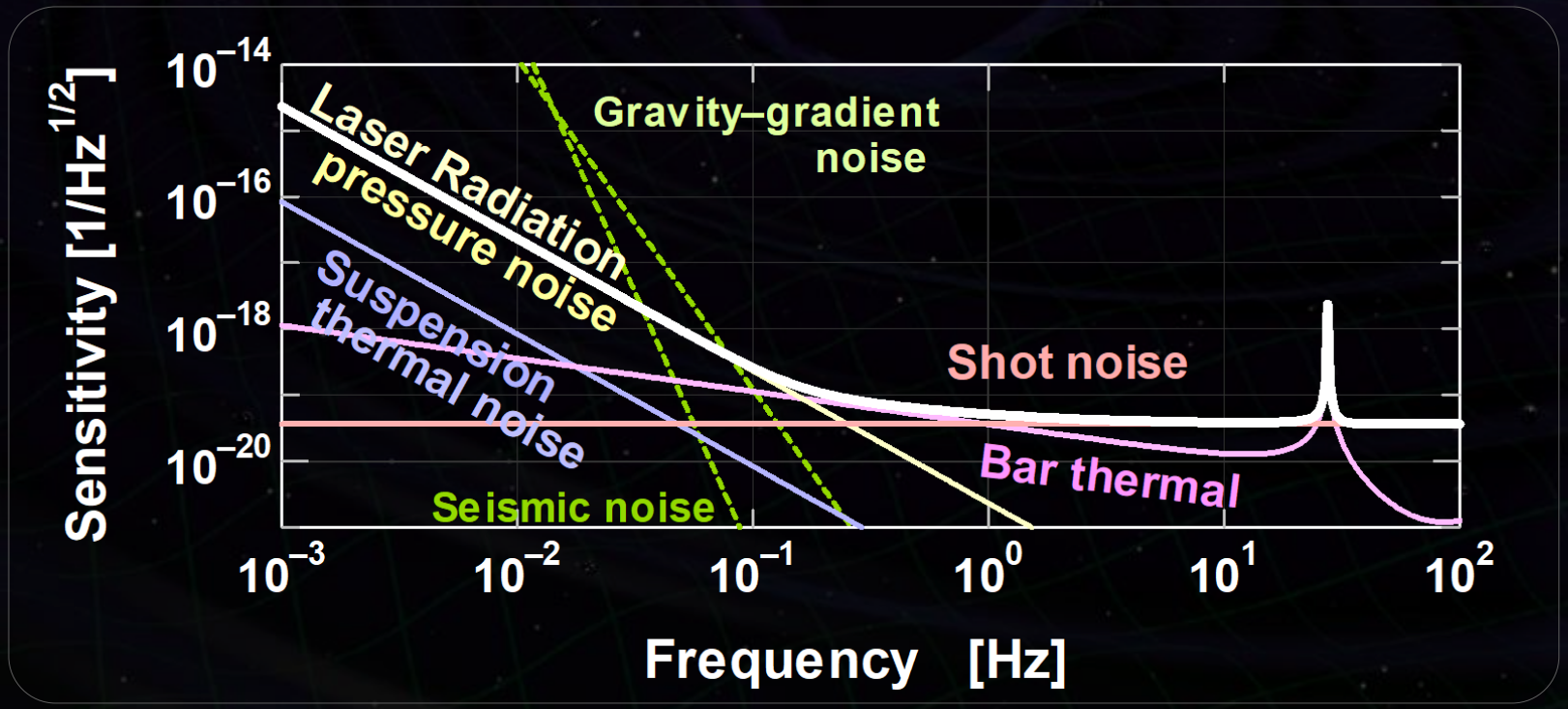
Torsion Bar is a sensitive Gravity Gradiometer.

It can be used for :

* Investigation of Gravity-gradient noises for 3G interferometers.
* Earthquake early alert.
* Tiny force measurements in Quantum noise, Space missions, Fund. physics,…

Fundamental Noise Level of 10-m TOBA

Practical parameters ⇨ $\tilde{h} \simeq 3 \times 10^{-19}$ [$\mathrm{Hz}^{-1/2}$]



Bar length : 10m, Mass : 7600kg
Laser source : 1064nm, 10W
Cavity length : 1cm, Finesse : 100
Bar Q-value : 10^5 , Temp: 4K
Support Loss : 10^{-10}

Laser Freq. noise < $10\mathrm{Hz}/\mathrm{Hz}^{1/2}$,
Freq. Noise CMRR>100
Intensity noise < $10^{-7}/\mathrm{Hz}^{1/2}$,
Bar residual RMS motion < 10^{-12} m

Phase-III TOBA

Prototype Developments

- Phase-I (2005-2010, Ishidoshiro, Ando, …)
  * Principle test and 0.1Hz GW observation
  * 20cm mass, Room temp, Poor seismic isolation
  * Two setups : Tokyo and Kyoto.
- Phase-II (2011-2015, Shoda, Okada, …)
  * Improved isolation design (Suspension + AVIT)
  * Principle test of multiple output configuration
  * Part of Cryogenics.

- Phase-III (2015-, Aritomi, Shimoda, …)
  * ~30cm scale, Cryogenic.
  * Upgrades in Suspension, Readout, Actuator,…

Phase-III TOBA Target

Strain sensitivity of 10^{-15} $Hz^{-1/2}$ at 0.1Hz.

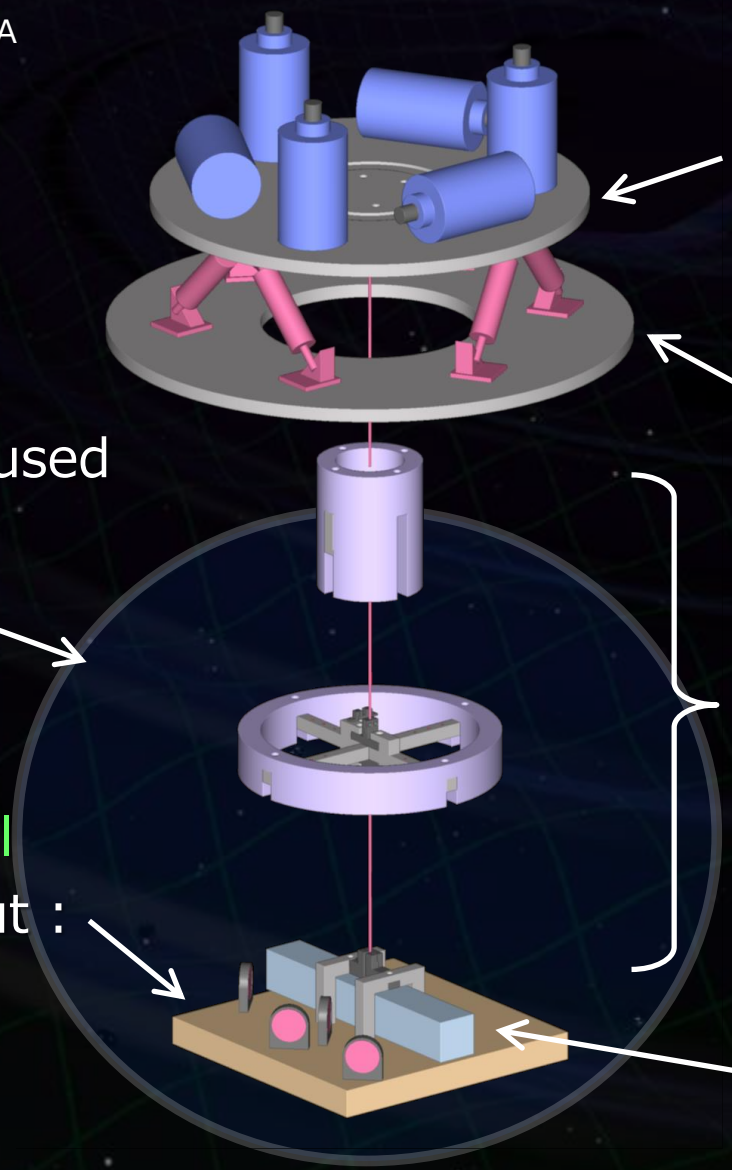
⇩

Multiple scientific outcomes expected:

* Observation of GWs.
* Direct measurement of gravity-gradient noises → Test bench for cancellation.
* Earthquake early alert.
* Tiny force measurements for Quantum noise, Space missions, Fund. physics,…

Conceptual Design of Phase-III TOBA

Figure: Tomofumi SHIMODA



Active seismic-isolation stage :
Geophone + Hexapod

Basement fixed to ground

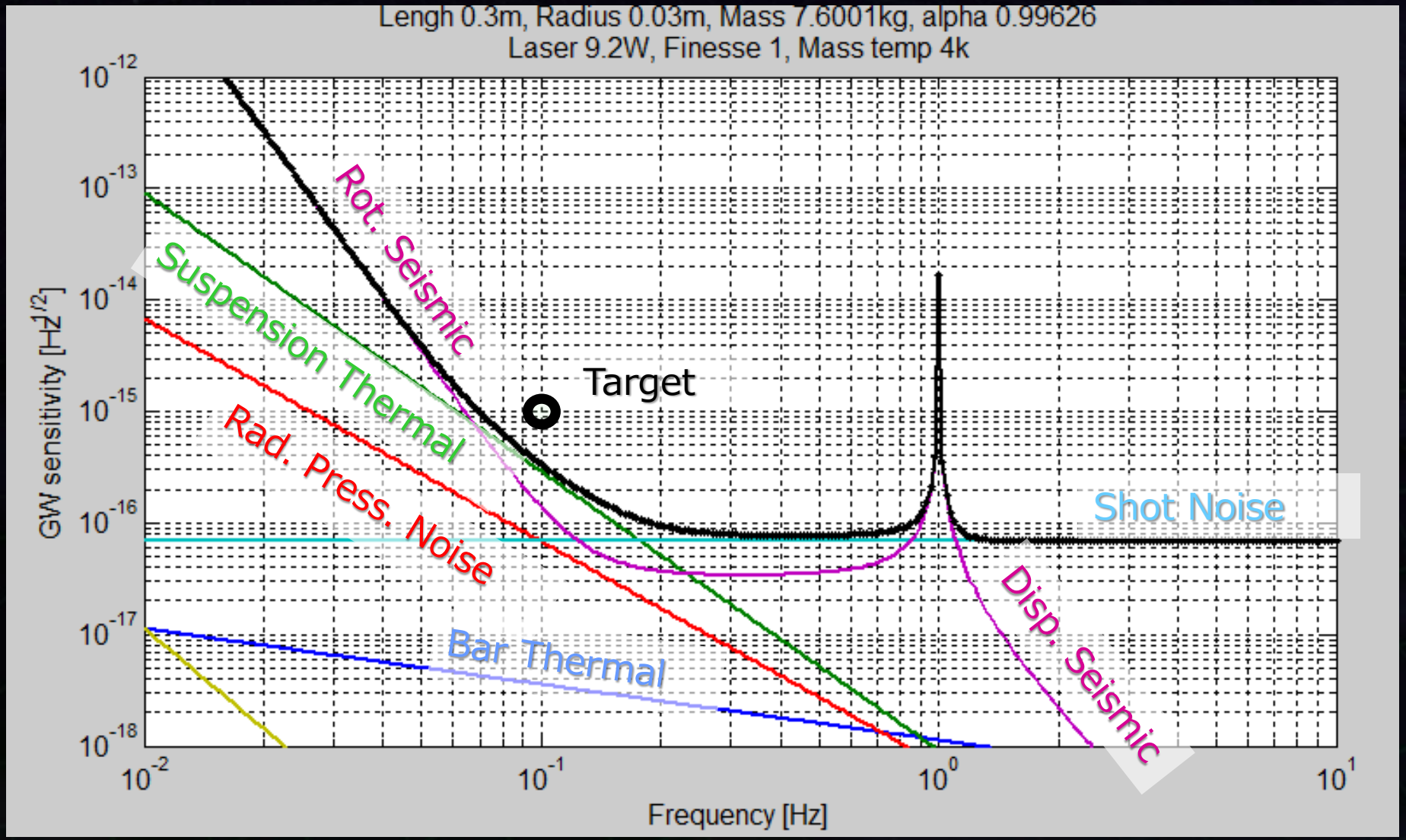
The setup is housed in a cryostat vacuum tank.

Passive isolation :
Triple suspension with damping

Monolithic optical bench for readout :
Power-recycled Michelson IFO

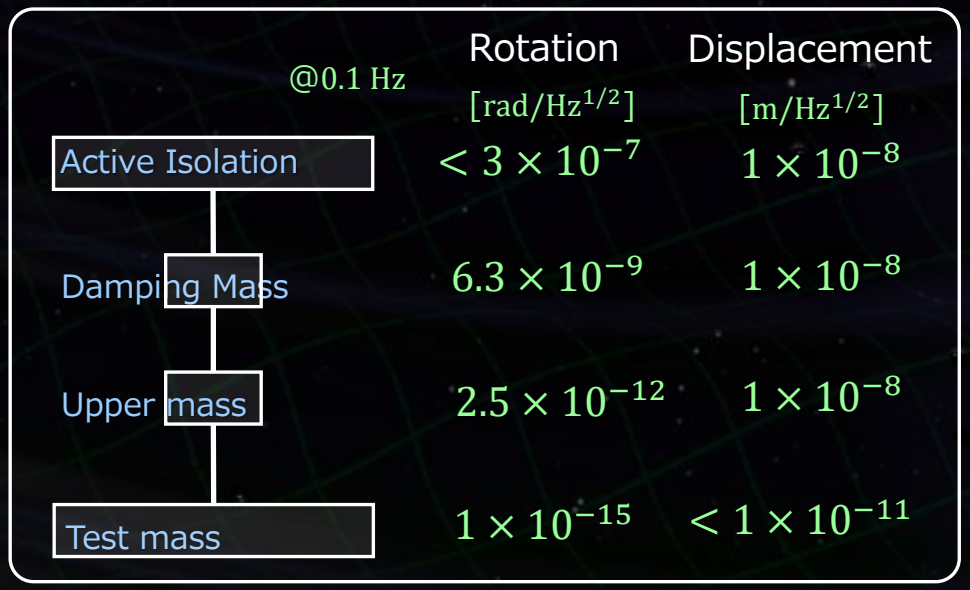
Monolithic test-mass bar, controlled using coil-coil actuator

Fundamental Sensitivity of Phase-III TOBA



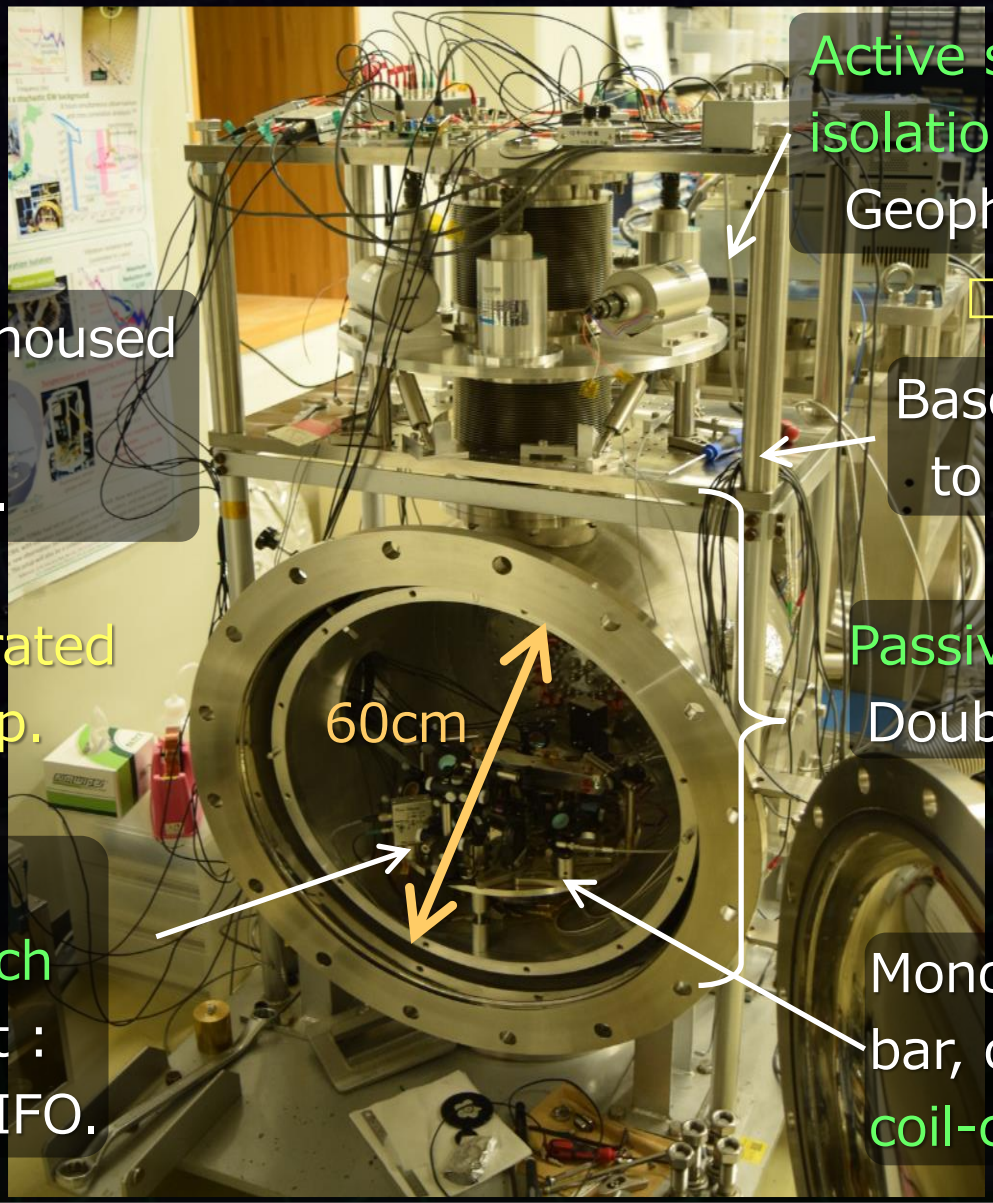
Tentative Parameters

- Test Mass:
  Copper (?), Length 30cm, Mass 7.6kg, Temp. 4K.
- Suspension:
  Silicon, Resonant Freq. ~2 mHz,
  Temp. 4K, Q-value $> 3 \times 10^7$
- Optical Readout :
  $\theta < 1 \times 10^{-15}$ rad/Hz$^{1/2}$
  Laser power > 0.1W
- Seismic isolation :
  Active isolation
  + Passive suspension
  (3 stages)



Recent Activities

Current TOBA Setup



Active seismic-isolation stage :
Geophone + Hexapod

⇨ Not used now.

Basement fixed to ground

Passive isolation :
Double suspension

Monolithic test-mass bar, controlled using coil-coil actuator

The setup is housed in a cryostat vacuum tank.

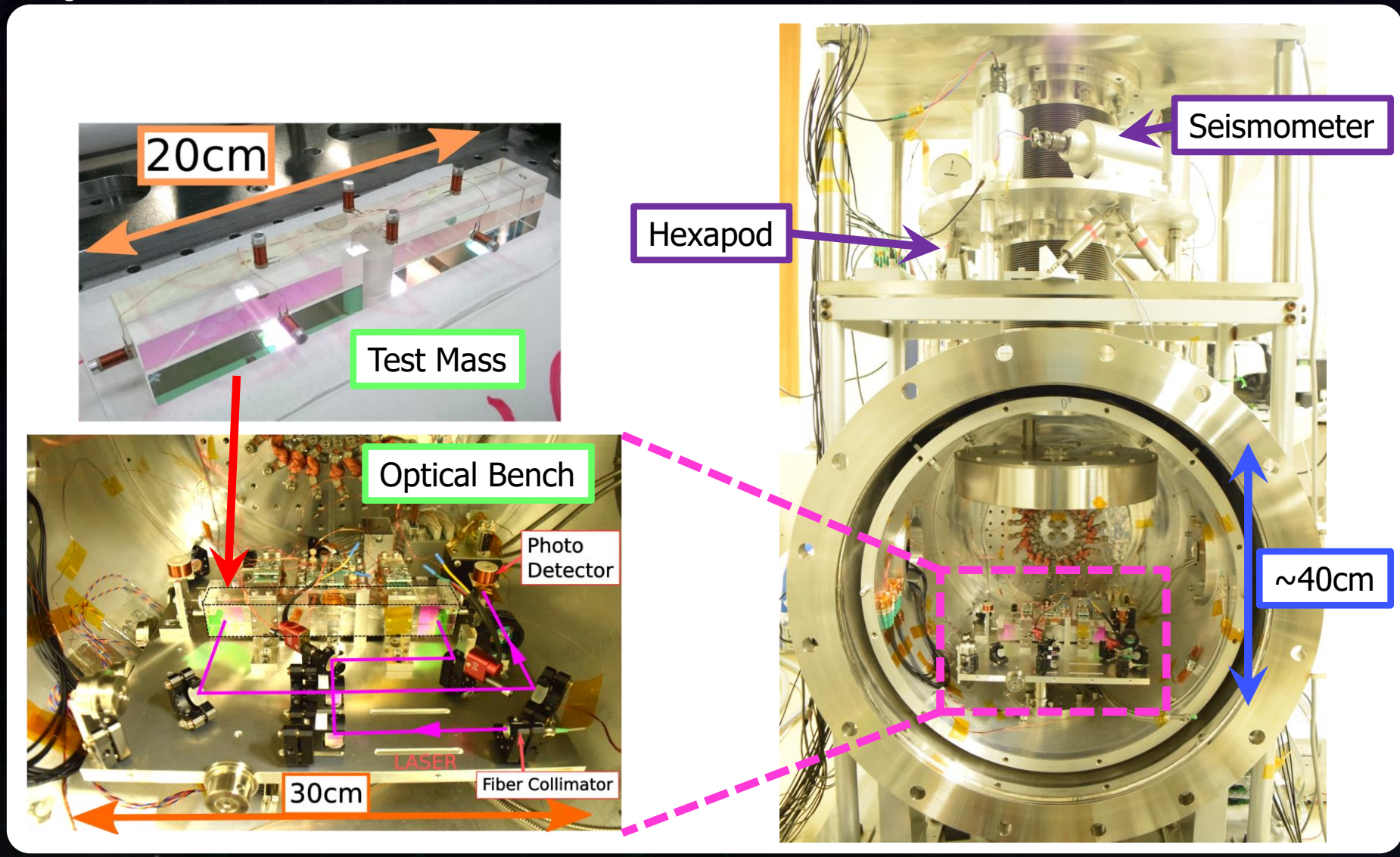
⇩

Currently operated at room-temp.

Suspended Optical bench for readout :
Michelson IFO.

Experimental Setup

Figure: Tomofumi Shimoda



Current Sensitivity

- Sensitivity $\sim 3 \times 10^{-8}$ $\mathrm{Hz}^{-1/2}$ at 0.1Hz (Jan. 2017)

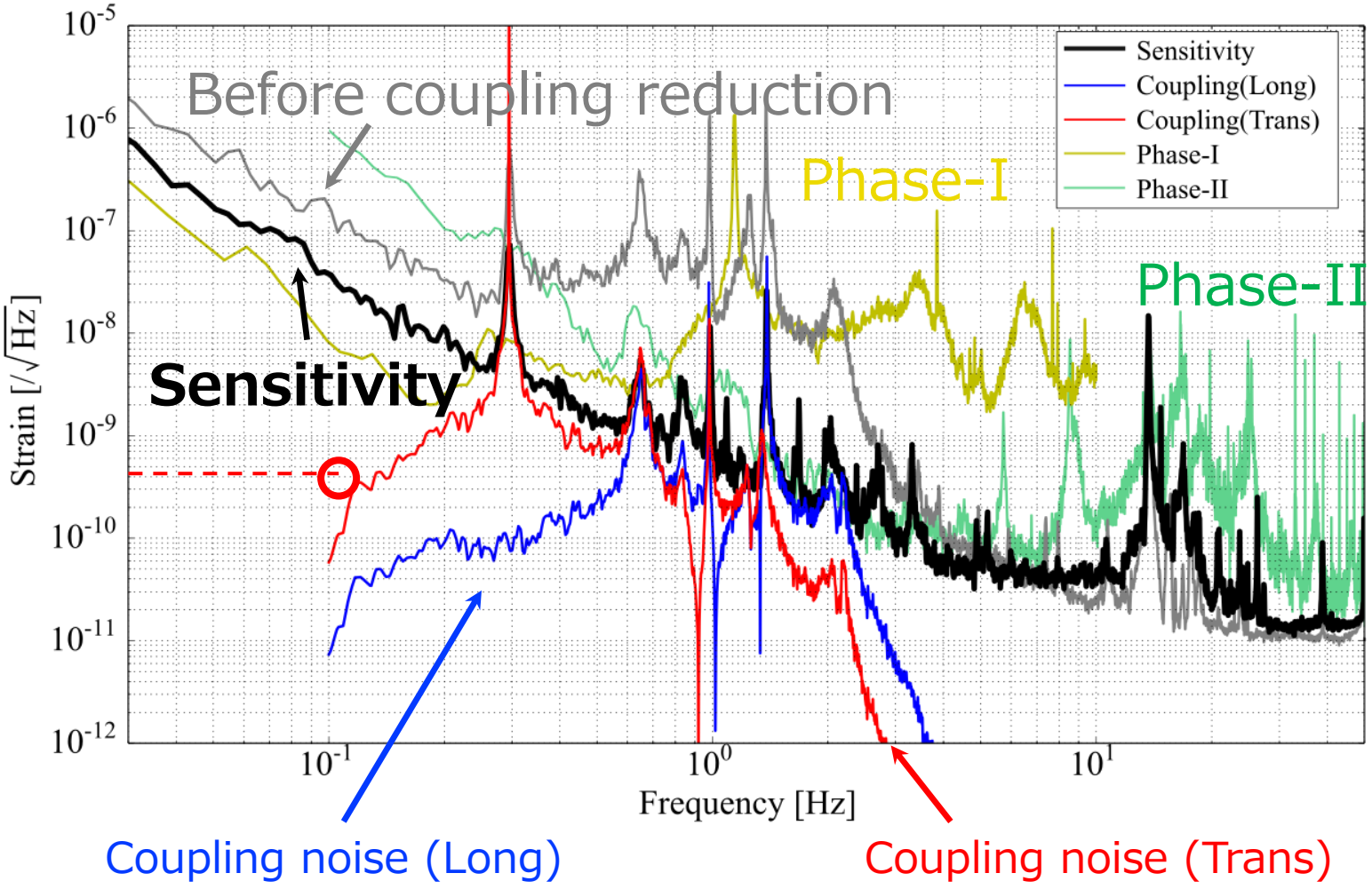


Figure: Tomofumi Shimoda

Current Noise Sources

- Current sensitivity is limited by actuator noise, (and also non-liner seismic coupling?).

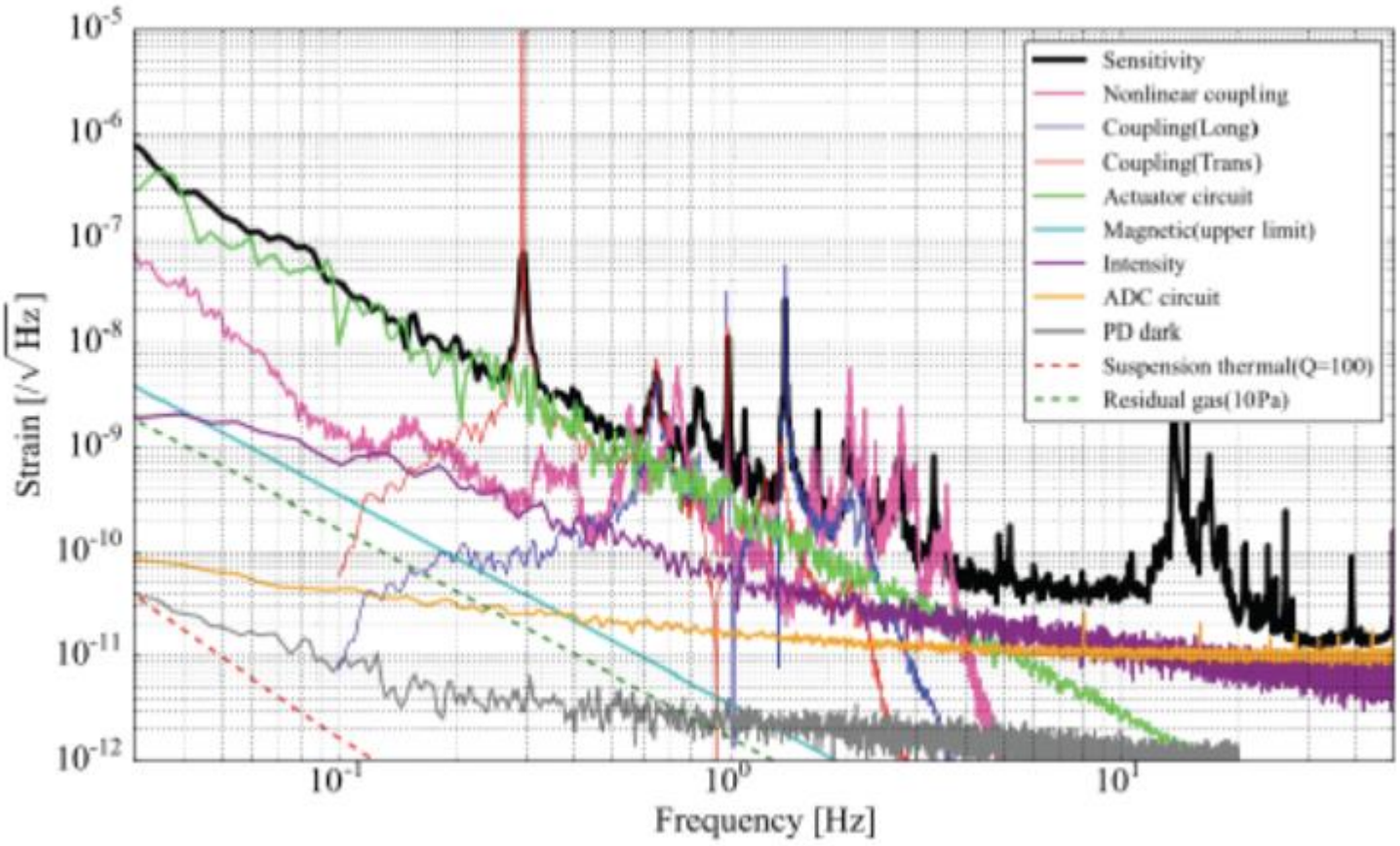


Figure: Tomofumi Shimoda

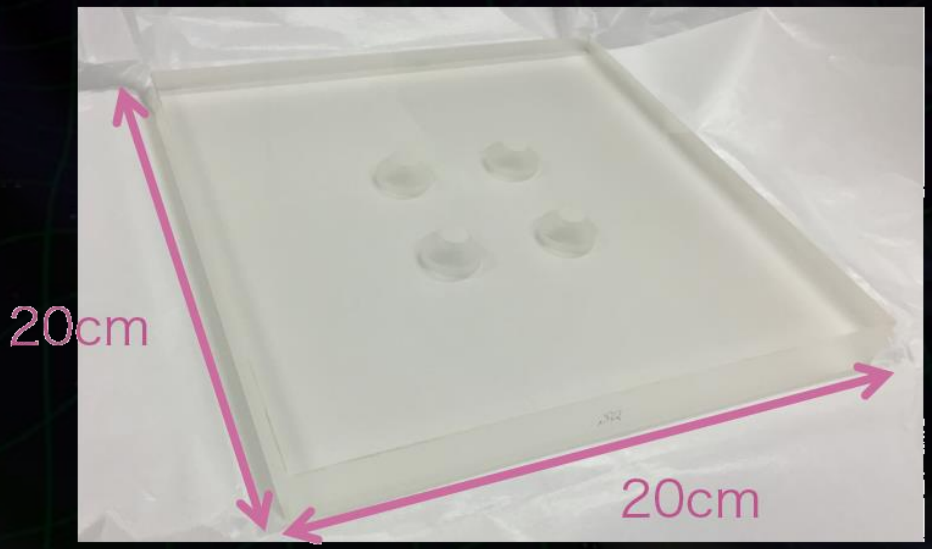
Current Activities

- Tomofumi Shimoda (D1 → Ph.D thesis in 2020.3)
  - * Finished master course.
  - * Designing the next set-up.
- Satoru Takano (M1 → Master thesis in 2019.3)
  - * Working on noise hunting and investigation of seismic noise coupling.
- Ching Pin Ooi (M2 → Master thesis in 2018.9)
  - * Measurement of Q-factors of various materials.
- Hiroki Takeda (M2, finishing his thesis)
  - * Development of monolithic interferometer
- Naoto Aritomi (D1)
  - * Finished master course.
  - * He will leave our group.

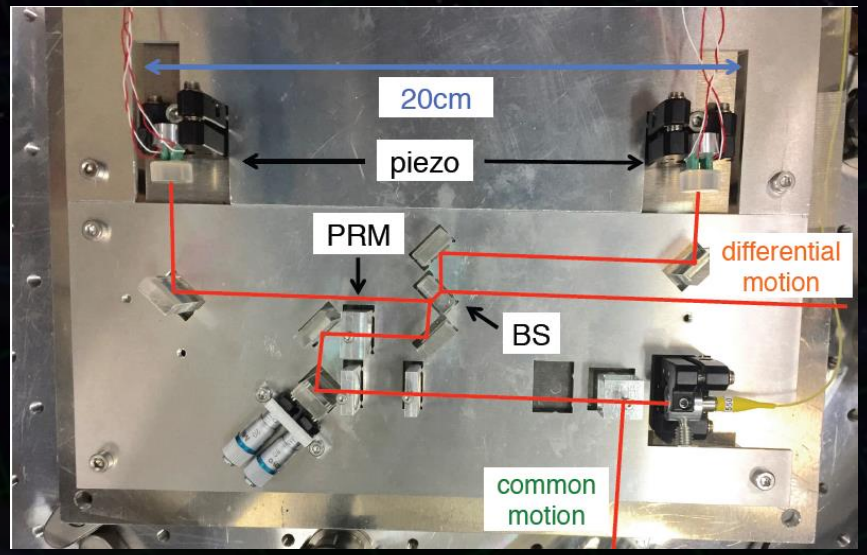
Monolithic Optical Bench

- Development of monolithic interferometer with Fused Silica components glued on metal bench.
  → Successful interferometer operation.

Photos: N. Aritomi



Fused Silica Optical Bench :
λ polish for surfaces



Monolithic Power-Recycled Michelson Interferometer on Aluminum Bench

Cryostat and Cryo-cooler

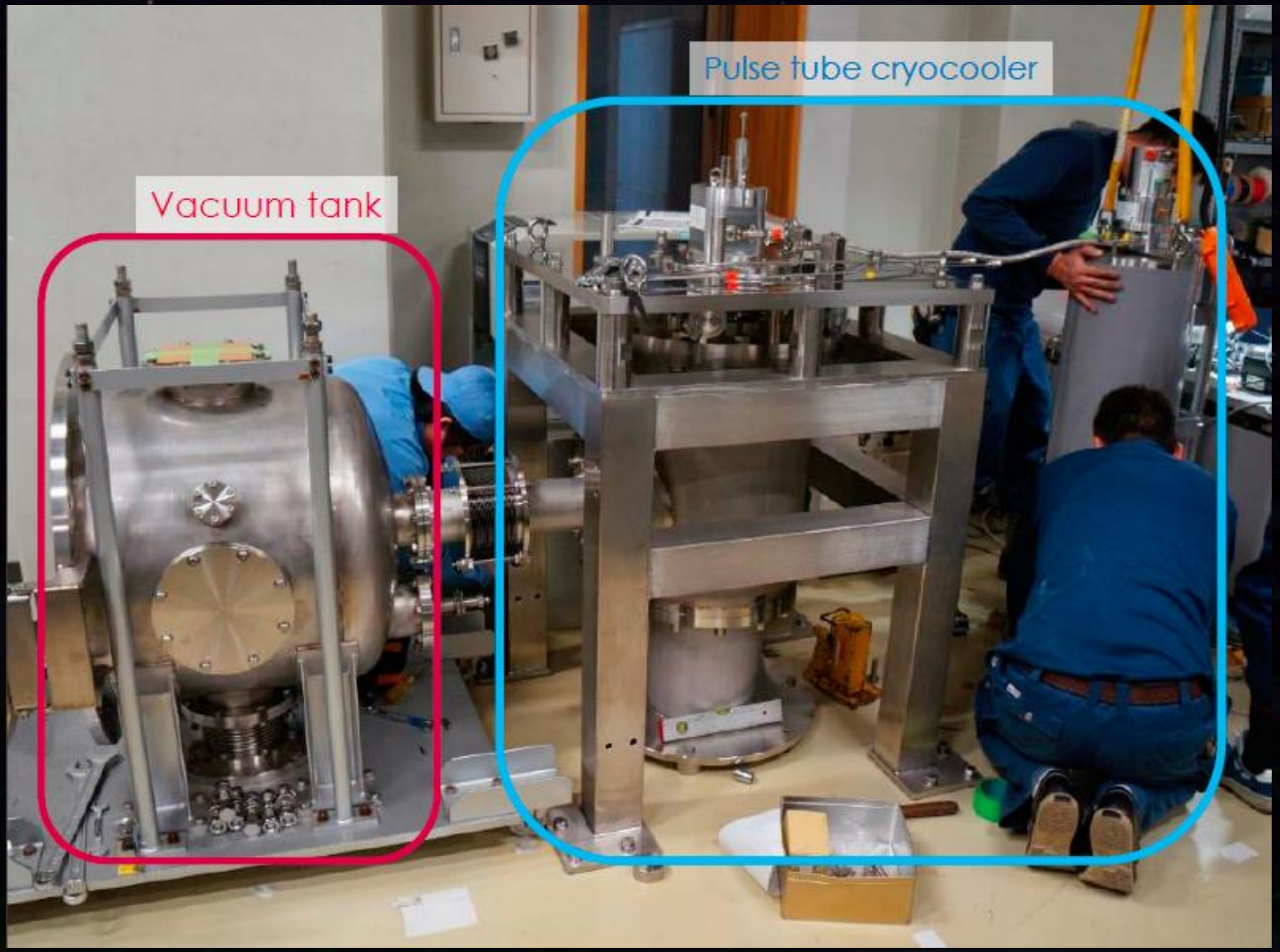


Figure: A. Shoda

Future Prospects

- Several-month time scale
  - * Noise hunting with current setup.
  - * Establish the procedure to make monolithic interferometer.
  - *Measurement of torsion-mode Q of various materials.

- Two-year time scale
  - * Upgrade the setup for Tomofumi's thesis.
    - New angler sensor using WFS technique?
    - Cryogenic operation.
    - → Target sensitivity :$\sim 10^{-14} \sim 10^{-15}$ $\mathrm{Hz}^{-1/2}$ at 0.1Hz

End